STEERED BEAM ULTRASONIC SENSOR FOR OBJECT LOCATION AND CLASSIFICATION

This application is a divisional of application Ser. No. 09/399,469 now U.S. Pat. No. 6,327,221, filed Sep. 20, 1999.

FIELD OF THE INVENTION

The invention relates in general to an apparatus and method for detecting the presence of an object within a compartment of a vehicle. More specifically, the invention relates to an apparatus and method that uses an electronically steered ultrasonic beam to measure the range, angular extent and angular direction of an object located within a compartment.

BACKGROUND OF THE INVENTION

Air bag systems have become a standard vehicle safety feature to prevent injury to vehicle occupants. Unfortunately, in certain circumstances, early first generation air bags sometimes caused injury to the vehicle occupants due to the indiscriminate nature in which the air bags were inflated. The air bags would inflate at maximum force regardless as to whether the occupant was a child or an adult, whether the occupant was properly seated to face the air bag, or whether the occupant was too close to the point of air bag deployment. The application of maximum deployment force of the air bags to children or adults of small stature has resulted in injury even in relatively low speed collisions.

In view of the problems associated with the first generation air bag systems, a variety of "smart" air bag systems have been developed in an attempt to prevent unwanted injuries from occurring due to air bag deployment. These second generation air bag systems include sensors for detecting the presence of an occupant within a vehicle. U.S. Pat. No. 5,906,393 issued to Mazur et al., for example, discloses a system in which a weight sensor is used to determine the presence of an occupant in a vehicle seat. Other systems have been developed to specifically detect the presence of a child seat. U.S. Pat. No. 5,901,978 issued to Breed et al., for example, discloses a system for detecting the presence of a child seat that utilizes ultrasonic transducers.

While the above-described systems are improvements over the first generation systems, they are generally limited in the amount of information they can provide to control air bag deployment. It would be preferable to provide a system that could detect not only the presence of an occupant, but also distance of the occupant from the air bag and the occupant's angular direction and angular extent. For example, as children are generally narrower in width than adults, it would be beneficial to provide some measure of the angular extent of the occupant to provide a simple method of determining if the occupant is a child or an adult of small stature.

Ultrasonic or acoustic range finding in itself has been applied in many applications including, for example, lens focusing systems for in cameras in which an ultrasonic range finder computes the distance to an object and adjusts the lens focus accordingly. In such acoustic range finding applications, an appropriate transducer generates an acoustic signal as a short duration pulse. The pulse is reflected off of nearby objects and is received by the same, or another, transducer. As the speed of sound in air is a known quantity, the distance of the object from the transducers can be calculated from the transit time of the acoustic pulse.

Ultrasonic range finders typically use ultrasonic frequencies which are inaudible to the human ear. These high frequencies have inherently shorter wavelengths, which lead to greater positional accuracy than audible frequencies. Some systems known in the art use several simultaneous signals with differing frequencies. These simultaneous signals are generated to provide at least one readable signal in the presence of acoustic interference.

Ultrasonic sensors are typically made from a single transmitter/receiver transducer. A brief ultrasonic pulse is transmitted, and this is reflected from a nearby object. The transducer, now used as a receiver, detects the reflected pulse. This type of sensor will give object distance information, but provides no angular position or extent information.

Phased array radar systems utilize a stationary array of transducers to generate object distance, angular extent, and angular position information. An array of many transducers driven at different amplitudes and phases can produce a lobe pattern of one narrow beam which is steerable over a wide angle. This technique is called aperture synthesis and it is used in phased array radar systems.

The beam is formed by the interference of the radar waves, a consequence of the principal of linear superposition. In linear superposition, the radiation of one source combines with that of another source to either increase or decrease the radiation amplitude at a point, causing constructive interference or destructive interference respectively. A well known example of this principal is the Young Experiment of 1802 in which light is passed through a pinhole to create a point light source, then it is through two other pin holes, finally the light is projected on a screen. A regular pattern of light and dark bands appears on the screen, which is caused by the interference of the two point sources. A more detailed analysis of the Young Experiment appears in D. Halliday and R. Resnick, "Physics for Students of Science and Engineering," Part II, Second Edition, John Wiley & Sons, Inc., New York, 1962, pp. 976–982. Further information may be found in Grant R. Fowles, "Introduction to Modem Optics," Holt, Rinehart and Winston, Inc., New York, 1968, pp. 62–66. The linear superposition effect is applicable to light waves, radar waves, and acoustic waves.

A similar steered beam system which uses a stationary array of transducers would be desirable for vehicle occupant detection. However, due to the inherent characteristics of radar wavelength and frequency, radar is not accurate enough for close range use in measuring the relatively small variations in distance between a passenger and an automotive air bag. Therefore, a device which uses aperture synthesis technology and facilitates accurate short range distance measurement is needed.

If an array of acoustic transducers were utilized, an interference pattern could be formed if the transducer spacing is about the same as the wavelength of the acoustic signal. If the speed of sound in air is about 344 m/sec, an ultrasonic transducer operating at a frequency of 68.8 kHz will have a wavelength of 5 mm, while higher frequencies will have proportionately smaller wavelengths. If two transducers are used and spaced apart by a wavelength, the transmitted beam pattern will be similar to the beam pattern shown in FIG. **1** in which a central main lobe is produced with corresponding side lobes. If a phase shift from 0–180 degrees is introduced between the transducers, the main lobe is steered to one side and the intensity of the side lobes is changed until a symmetric lobe pattern is achieved at a 180 degree phase shift as shown in FIG. **2**. Thus, a simple two